Jordan Phil Sc. 16 (1949) p269

is an attack on v. Neumann's subjectivism

— Incoherence is due to macroscopicity

not to the mind of the observer.

Moreover incoherence due to Brownian motion for α-particle emissions.

at T=0°K coherence would return.

refers to Margenau Phil. Sc. 4 (1937) p337

distinguishes measurement from state preparation for the first time.

ranslations required.

P. Jordan — Zeits. f. Phys. 44 473 (1927)

O. Klein, P. Jordan — ibid 45 751 (1927)

E. Wigner, P. Jordan — ibid. 47 631 (1928)

V. Fock — ibid 75 622 (1932)

Jordan, Pauli — ibid 47, 151 (1928)

Heisenberg, Pauli — ibid 56 1 (1929)

" 59 168 (1930)

H.A. Kramers Quantum Mechanics. Translated by D. ter Haar.

Has short section on Kramers' work on [illegible] on p. 453. Historical notes are given.

Amsterdam — North Holland 1956 (?)

Also section on Field theory, Corpuscular theory of Radiation.

He says one cannot define current operator in relativistic Boson fields — hence one cannot speak of particles in the same sense as in N.R. Q.M. of a system of point particles.

Rel. theory overlooks no examples of [illegible] less other features energy only necessary (of no concern)

Aharonov, Bergmann, Lebowitz

'Time Symmetry in the Quantum Process of Measurement':

P. R. 134 (1964) p. 1410.

See also Grunbaum in Schilpp ed. Rudolf Carnap

The Interpretation of Quantum Mechanics

J. Bub. D. Reidel. 1974

very good account of hidden variable theories & q. logic with some discussion of model theory for q. logic. very good discussion of its significance for the understanding of Tarski algebra → examples with algebra of sets (of maximal set of props implied by given prob i.e. algebra of ultrafilters) this is content of Stone's representation theorem.

Prob Found. Phys. 3 p.29 (1973)
Refutation of Bell-Wigner

rejects $p(s/t) = p(s \wedge t)/p(t)$
does not hold for incompatible observables
nor even for compatibles
due to intransitivity.

we must have a non-Boolean rule for conditional probs. in the Boolean prob-space theory.

Prob. theory is strongly non-Boolean
cannot be interpreted as a calculus on Boolean logical space.

Fine repts Bell-Wigner locality result p. 257 – 259
refers to Bob. Foun. Phys. 3 (1973) 29-44.

Synthese Dec. 1974

Lutzen criticism of Kochen Specker proof p. 331 – 372.

Cartwright on macroscopic dorables p. 229 – 242.

Wigner's argument $A_1\ A_2 \quad B_2\ B_3 \quad [A_i\ B_j] = 0.$
spectrum on $\{1, -1\}$ all 4 operators.

$$P^{\phi}_{A_1, B_3}(1,1) \leq P^{\phi}_{A_2 B_3}(1\ 1) + P^{\phi}_{A_1 B_2}(1,1).$$

$A_i = \sigma_A \cdot d_i \quad i = 1, 2$ three g's $d_1\ d_2\ d_3$.
$B_j = \sigma_B \cdot d_j \quad j = 2, 3.$

Lutzen criticises Kochen Specker
(1) Commensurability can be defined until different "laws" ... then partial operations are not preserved $(f_1+f_2)B \neq (g_1+g_2)C$ for $f_1(B) = g_1(C)$, $f_2(B) = g_2(C)$
(2) Commensurability of two for simultaneously doubles of $B$ or $C$) can be measured — not two clusters for the ... example.

Fine's makes the point essentially
that joint probs in QM are not to be derived
from joint probs in HV phase space of hidden
variables – this association depends on the
product rule, which may collapse
– better to regard every quantity as having
a value but joint probs given by Q.M. – each
variable is in its own sample space.

Gleason (also Varadarajan)

$\langle F \rangle = \mathrm{Tr}\, F\, U$ $\quad$ $U = \sum \lambda_i P_i$

Frame function $\sum_\alpha f(P_\alpha) = W$ for any orthonormal basis.

$f_U(x) = \langle U \rangle$

Regular frame f. if $\exists\, U$ s.t. $f = f_U = \langle U \rangle$.

Prob $f = \langle P \rangle$. $\quad$ $\cancel{P^2 = P}$ $\quad$ ~~Tr AB=~~

$\sum \lambda_i = \mathrm{Tr}\, U$. $\quad$ $\cancel{\mathrm{Tr} P} = 1 - 1$

$P^2 = P$ $\quad$ $\mathrm{Tr}\, AB = A_{ij} B_{ji}$

$\langle P \rangle = \mathrm{Tr}\, P$.

$\Rightarrow$ 1. Sep continuous frame function on $R^3$ is regular. by harmonic analysis.

2. Every frame function is continuous

$\mathrm{Tr}\, U A U^{-1} = \mathrm{Tr}\, A$

Wess, Zumino   Supergauge   N. Phys. B70 (1974) p. 39-50.

discuss supergauge transformations in four-dimensional space time. - similar to a Lie algebra.

refer to Neveu, Schwarz. N. Phys. B31 (1971) p. 86.

refer to Kober, Nielsen   N. Phys B.10 (1969) 633

1) Combley, Picasso   Phys-Rep. 14 p. 1 (1974)
~~the~~ Muon (g-2) precession experiments.
very good account
of the muon experiments
refer to Lautrup et al Phys Rep
, Rich, Wesley R.M.P. for earlier summaries

See for dual resonance, strings   Mandelstam Phys. Rep. 13 (1974) p. 259.
Rebbi .. 12 (1973) p. 1

M. Jammer: The Philosophy of Quantum Mechanics 1974

gives very detailed reference to Interpretations of QM
begins with Schrödinger's electromagnetic interpretation by analogy with wave phenomena, the hydrodynamic analogy of Madelung, De Broglie's Double soln.

then discusses Indeterminacy Relations in ch. 3
refers to Condon for anomalies of uncertainty relations
[illegible] for hydrogen. (Sc. 69 (1929) p.573)

Ch. 4 discusses Bohr on Complementarity, the Como Lecture, 1927.
refers to Weizsäcker's distinction between circular comp (never contained in classical model), parallel comp (one contained in classical model)

ch V is on the Bohr-Einstein Debate.
5th Solvay Conference 1927.
Bohr says his philosophy derived from Einstein's method in relativity. E. comment "A good joke should not be repeated too often" (word to Frank).

6th Solvay Conference 1930.
photon in a box $\Delta E \Delta t$ expt
weighing clock

Bohr's reply. used uncertainty in clock rate. from G.R. ?

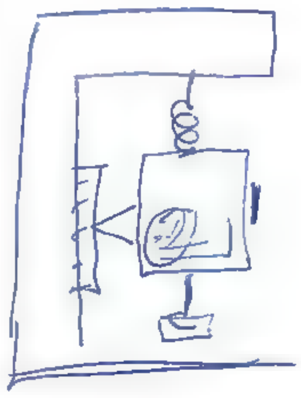
$\Delta T$ related to $\Delta q$ $\hookrightarrow$ position of clock

related to $\Delta p$ momentum of clock.

must be smaller. than $T g \Delta m$.

when $\Delta m$ is error in weighing

$\Rightarrow \Delta T \Delta E \geq h$.



So G.R $\Rightarrow$ consistency of Heisenberg relations

we cannot reverse this implication

But $\sim$(G.R) $\Rightarrow$ $\sim$(Heisenberg)

$\therefore$ Heisenberg $\Rightarrow$ G.R.

But we can also derive consistency by assuming collision $\rightarrow$ indeterminacy

instead mass of box in a

or velocity of box $\rightarrow$ $\Delta T$ as required.

J. refers to many different interpretations of what $\Delta E \Delta T$ signifies – in particular refers to the Mandelstam-Tamm interpretation (as followed by Messiah)

ch VI deals with E.P.R.

Replies from Kemble, Bohr, Schrodinger (+ cat), Furry, Margenau.

J. refers to two unresolved arguments:—

(1) Epstein Am J. Phys. 13 (1945) p.127 only time dependence.

(2) Cooper. Proc. Camb Phil. Soc. 46 (1950) p 614.
separation in space after interaction tends to new defn of measurement operator. EPR argument breaks down:
either (1) systems cannot be separated
or (2) if they are, they no longer have self-adjoint ops for the momenta

J. then refers to Sharp (system never separated)

Turner says q p can have simultaneous values
$\Delta p$ $\Delta q$ refer to ensembles only

Ch 7 deals with hidden variables
Stances they cover originally of hidden variable theory.

deals with Von N's proof
Bohm's 1952 hidden variable theory which starts from hydrodynamic analogy with $\psi = Re^{iS}$
(cf Madelung)

Then came work of Gleason showing that additivity of expectation values for commuting operators alone is sufficient.

Jauch & Piron recasted proof in terms of lattice theory (1963)

then Bell (1966) gave his example of spin-½ hidden variables — also his 1964 proof of Non-Locality for coherence of 2 particles.

Kochen & Specker proof given as a simplified version Partial algebra defined. Mapping $f: \Gamma \to R$ preserves partial algebra, i.e. leads to a homomorphism of partial algebra into $R$, or by extension algebra (idempotents) two Boolean algebra $\{0, 1\}$ ($\equiv Z_2$). But this is found to be impossible for dim $\geq 3$.

Special example. $J^2 = J_x^2 + J_y^2 + J_z^2$ $n=2$, $l=0$, $s=1$ for orthohelium $J_x^2$, $J_y^2$ $J_z^2$ & $J^2$ all commute. $J^2 = 2$

Hence one only of $J_x^2$, $J_y^2$, $J_z^2$ is zero

Simple proof due to Fox Friedberg.

$\alpha$-prop for direction $\alpha$ prop $L_{\parallel} = 0$.

Then only one of 3 orthog. $\alpha$-props is true (1)

Now $x+y$, $x-y$, $z$ are orthog. also $x+z$, $x-z$, $y$.

Hence $x+y$, $x-y$, $x+z$, $x-z$ cannot all be false.

Now each is orthog. to $d_1 = y+z+x$ or $d_2 = y+z-x$.

So $d_1$, $d_2$ cannot both be true.

angle between $d_1$ and $d_2$ is $\cos^{-1}(\frac{1}{3}) \simeq 70^\circ = \alpha$

So Two d-props making an $\angle \alpha$ cannot both be true.

Now take $d_3$ in $xy$ plane $\angle \alpha$ with $y$.

If $d_3$ is true $z$ is false, ~~Hence~~ and $y$ is false.

and Hence $x$ is true.

or if $\beta = \pi/2 - \alpha$.

Then Two d-props which make an angle $\beta$ ($\simeq 19^\circ$) with one another.

Hence any d-prop $\Rightarrow$ every other d-prop.

So if $\angle d = 0$ in one direction, it is 0 in all directions, which contradicts (1).

But we have assumed truth value of a d-prop does not depend on which other d-props are being measured – once we select different bases truth-values might alter – then we have Bohm's theory works (cf. also Belinfante)

Finally there is a discussion of Van Stakod 6
"proof" of EPR non-locality and Tucker's comments
and Freedman, Clauser
and Clauser Horne, Shimony, Holt for ~~proof of~~
experimental check on Bell's inequality

<u>ch. 8</u> deals with Q. logic

3-valued logic due to Lukasiewicz (1920).

<u>Non-Distributive Logic</u> Birkhoff, Von Neumann (1936)
discussion of Popper's (1968) paper. Popper misunderstood
what von N. meant.

<u>Many-valued logic</u>
Logic is ~~a theory of reality~~ empirical or
"relativity of logic". promoted by French school.
P. Hertz, G. Bachelard, F Gonseth, Z. Fougier in
1930's. → Février's 3-valued logic
[also Lewis, Hahn, Carnap in the 30's] → Reichenbach (1944) in his
book on Philosophic Foundations of QM.
adopted by Turquette author of standard work on
many-valued logic (1952)

Refers to Nagel. "Logic without Ontology" rep. in Feigl & Sellars
p. 191 (Readings in Philosophical analysis)
Born criticised Reichenbach in 1948 for "explaining" 3-valued
logic using 2-valued logic.
But R. was supported by Putnam. (1957)

J. also discusses. Segal's algebraic approach to QM
(developed from Jordan) and Rodley's
axiomatic treatment (1963) - developed by Jauch
Piron at Geneva. (1969).
Different approach is Mittelstaedt (1959 onward)
following logical ideas of P. Lorenzen. (operative logic)
In Section 8.6 J discusses relation of quantum logic
to logic. Non standard logic should be
used to formalize arguments in the language.
We should re-write Principia Mathematica in
non-standard terms (cf Heyting-Brouwer and
Intuitionist logic)
Piron showed that $a \leq b$ (or $a \Rightarrow b$) is not
a yes-no proposition. $a \leq b$ functions like $\Rightarrow$
since it infers between a value, b is true, but
we can give no meaning to $a \leq (b \leq c)$ ...

converted to $a \to (b \to c)$ 8

cf Piron Helv. Phys Acta. 37 (1964) p 439.

But there may be generalizations of $a \to b$ which reduce to latter on Boolean lattices. cf Mittelstaedt

Z. f. Naturf. 27a (1972) p 1358.

But Jauch & Mittelstaedt both show derivation of Q. Logic from ordinary logic.

But D. Finkelstein & H. Putnam (Boston Studies 5) do regard Q. logic as a new full-fledged logic similar to non-Euclidean geometry replacing Euclidean.

But Fine endorsed Putnam's views.

Finkelstein's introduces operational defn of connectives using filters. But a & b involves a set of filters which is not experimentally possible (Healey's criticism. Synthese 21 (1970) p 1)

Suppes suppports Q. Logic on probabilistic grounds — absence of joint distributions ⟹ logic as non-classical. Phil. Science. 33 (1966) p. 14

But Suppes criticised by Fine (1968)

Putnam says. $q_1 \cup q_2$ . . . valid; $p_1 \cup p_2$ . . . valid. $q$
But $q_1 \cap q_2$ is always false.
$q$ is incompatible with $p_j$ for all times, all $j$.
But is not incompatible with $(p_1 \cup p_2 \cup$ - - - $)$
i.e. we cannot deduce since $(q_i \cap p_1) \cup (q_2 \cap p_2)$ —
is false then $q_i \cap (p_1 \cup p_2 \cdots)$ is false.
Indeed if $q_i$ is true then individual $q_i$ cannot be combined with $p_1$ or $p_2$ - - , but it can be combined with $p_1 \cup p_2$ - - . The deduction is from non-distributivity results itself.
Heelan tried to refute Putnam by Putnam in 1968 — [illegible] classical logic to prove classical logic is wrong (?).
We also have work of Watanabe (Boston 5 etc)
who says correspondence between conventional logic & Boolean lattice is a consequence of Frege Principle (Every Predicate determines a set)
So predicate calculus → set theory → Boolean algebra.
W. rejects Frege's Principle (cf Russell's paradox)

Frege Principle breaks down when object & observer interact as in QM & psychology (cf also Locke's 2nd qualities which depend on observer as well as object) 

So W, follows Peirce Principle. Implication is basic logical operation. W also derives ∧ & ∨ from → and allows for possibility of non-distributivity.

There is a domain of inference where usual logic applies so usual logic can function as a metalogic in terms of which the new logic can be explained.

cf also Zadeh's theory of fuzzy states (1965)

In final section J. refers to work by Von Weizsäcker to derive laws of QM as conditions under which experience becomes possible (cf Kant) and Ludwig who regards macrophysics as pre-eminent. Q.M. is not the most fundamental theory. "It is hard to believe that Q.T of $10^{24}$ atoms is exact theory of a table.

In ch. IX J. discusses stochastic interpretations 11
refers to Wigner distribution, Regal's paper.
also Margenau, Cohen. Von Bopp. and others.

In ch X J. discusses statistical interpretation
adopted by Kemble in his book on QM.
→ Popper and Lande'.
Pearl has attacked single state concept. Am. J. Phys. 36 (1968) p 211.
(also Ballentine. But Groenewold disagrees,
adding keeping to the statistical interpretation..
→ (value on subject of the statistical operator.)

In final chapter XI J. discusses problem of measurement.
(1) Von N's theory is emphasized.
(2) London, Bauer elaboration (1939) stress role
of mental activity. → (Phil. Sc. 4 (1937) p 337.
J then discusses Margenau. Measurement may determine
a state after or reveal a state before (cf also
Landau, Peierls (1931) who showed in general
that measurements perturb state (dependence of
Von N. theory of Wigner, Araki, Yanase)

Ludwig concluded only position measurements could be repeated with same result. 12

Jordan (Phil. Sc. 16 (1949) 269) introduced idea that apparatus must be macroscopic → irreversibility → statistical mechanics is key to measurement problem.

This idea was pursued by Ludwig (in his book Grundlagen der Quantenmechanik 1954 et al.)

L. introduced macroscopic observables and discussed how classical physics can be "extracted" in limit $h \to 0$.

J refers to Van Kampen's work.

then to D.L.P. (prompted by Ludwig) supported by Rosenfeld, but criticised by Jauch and Wigner's Yanase (1967), also Bub (1968)

J. also has digression on Renninger's "negative-result measurement".

J. also discusses Wigner's proposed effect of mind on physics.

J. then discusses Rosenfeld's Coherency theory.

refers to L Durand Phil. Sc. 27 (1960) p. 115. for discussion how " peculiarly quantum-mechanical effects are small relative to the accuracy with which classical observations may practically be made.

But Durand has been criticised by Fine (Proc. Camb. Phil. Soc. 65 (1969) p 111)

J then turns to Everett's Many-Worlds theory developed by de Witt, , Graham — yields its own interpretation. Supported by Wheeler but incredible.

Finally J. refers to Fine's unpublished proof. P.R. D2 (1970) p2783. for possible to Realism. developing an idea of ~~A. S.~~ Wigner, d'Espagnat, Earman's Phenomeny, and finally gives reference to george, Prigogine's Rosenfeld

Final comment on Rosewell. "A new look at the Q.M. problem of Measurement. Am. J. Physics 40 (1972) p. 1431, who says new objective version of QM need be developed, which does not incorporate the notion of measurement in its basic postulates at all.

Quote from Joubert "It is better to debate a question without settling it than to settle a question without debating it"

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Jammer Philosophy of Quantum Mechanics

Bell's hidden-variable example:

$A = \alpha + \beta \cdot \sigma$ $\quad \alpha, \beta$ real. Possible results for A

$a_1 = \alpha + |\beta|, \; a_2 = \alpha - |\beta|$ . Take $\psi = \begin{pmatrix}1\\0\end{pmatrix}$

$\langle A \rangle = \alpha + \beta_z$

then $a(\lambda, \psi) = \alpha + |\beta| \, \mathrm{sgn}\left(\lambda|\beta| + \tfrac{1}{2}|\beta_z|\right)$

$\mathrm{sgn}\, x$ , $x = \beta_z \; \beta_x \beta_y$, $\beta$'s non-zero
value in this order

Take $\beta_z \neq 0$ , $\beta_z > 0$

then $\langle A \rangle = \int_{-\frac{1}{2}}^{\frac{1}{2}} d\lambda \left[\alpha + |\beta| \, \mathrm{sgn}\left(\lambda|\beta| + \tfrac{1}{2}|\beta_z|\right)\right)$

$= \alpha + |\beta| \left\{ \left[-\lambda\right]_{-\frac{1}{2}}^{-\frac{1}{2}\beta_z/|\beta|} + \left[\lambda\right]_{-\frac{1}{2}\beta_z/|\beta|}^{1/2} \right\}$

$= \alpha + |\beta| \left\{ \tfrac{1}{2} + \tfrac{1}{2}\beta_z/|\beta| + \tfrac{1}{2}\beta_z/|\beta| - 1/2 \right\}$

$= \alpha + \beta_z$. , similarly for $\beta_z < 0$.

Bell's Inequality $\quad A(a, \lambda)$ is result of $\sigma(1) \cdot a$ $(\pm 1)$

$B(b, \lambda)$ is $\quad$ .. $\sigma(2) \cdot b$ . $(\pm 1)$

for QM. $P_{QM}(a, b) = \langle \sigma(1) \cdot a \; \sigma(2) \cdot b \rangle = -a \cdot b$ for singlet state.

$P_{h.v}(a, b) = \int \rho(\lambda) A(a, \lambda) B(b, \lambda) \, d\lambda$

Def. of Hidden variable

(1) hidden variables $\lambda$, defy. space $\Gamma$

(2) Each $\psi$ is associated with a prob. measure $\rho_\psi(\lambda)$ on $\Gamma$.

(3) each observable $A$ is associated with single-valued real function $f_A : \Gamma \to \mathbb{R}$.

(4) $M$ is a measurable subset of $\mathbb{R}$ and $\mu_\psi^A$ is Q.M. prob. measure such that $\mu_\psi^A(M)$ is prob. value of $A$ lies in $M$.

Then $\mu_\psi^A(M) = \rho_\psi[f_A^{-1}(M)]$

or $\langle A \rangle_\psi = \int_\Gamma f_A(\lambda)\, d\rho_\psi(\lambda)$

non-contextual h.v. $f_A(\lambda)$ does not depend on values of other observables which are compatible with $A$ and which may be measured also

local h.v. $f_A(\lambda)$ for measuring $A$ on $S_1$ in state $\psi, \lambda$ does not depend on the kind of measurement (or its outcome) performed on a second system $S_2$, spatially separated from $S_1$.

Comment on H. Brown

cf Park: International J. Theor. Physics
$\underline{8}$ (1973) p. 211

More discussion of Park $m_1 \supset m_2$ distinction
— Non-disturbing measurements, failure of projection postulate, reference to Park Found. Phys 1, (1970) p. 23. $\psi\alpha \to \psi\psi$, $\psi\alpha \to \alpha\psi$
↳ Mentions — ambiguity for physical components only when eigenvalues of $\rho$ are degenerate.

$|u_1\rangle\langle u_1| + |u_2\rangle\langle u_2|$

$\to |\alpha\phi_1 + \alpha\phi_2\rangle\langle\alpha\phi_1 + \alpha\phi_2| + -$

$|\alpha|^2 \phi_1\phi_1 + |\alpha|^2 \phi_2\phi_2 + \alpha\alpha\,\phi_1\phi_2$

$\alpha\rho_1 + \beta\rho_2 = \gamma\rho_1' + \delta\rho_2' = \rho$

$\alpha^2\rho_1 + \beta^2\rho_2 - \alpha^2\rho_1' + \beta^2\rho_2'$

$\gamma = \lambda \quad = \alpha\rho_1' + \beta\rho_2'$

$\alpha(\rho_1 - \rho_1') = \beta(\rho_2 - \rho_2')$

$\alpha$

use (P1) and write eq. no's on left (1) write equation.
(P2)

on P1:

Bunge, M. "Physical Time: The Objective and Relational Theory. Philosophy of Science. 35, 1968, pp. 355 – 388.

Quote: If a process is T-invariant then its laws are T-invariant

Converse is not true.

cylinder $x^2+y^2=1$
as to plane $z=0$.

~~Chalmers does not discuss leading up to gravity~~

Boolean algebra . J. Bell

Smallest filter containing subset $X$ of $B$ is said to be generated by $X$. Principal filters are generated by single element

$\{y \mid x \leq y\}$ is principal filter of $x$.

hull of homomorphism is $\{x \in B \mid h(x) = 1\}$
kernel . . . . $\{x \in B \mid h(x) = 0\}$

Ultra filter is a filter which is not contained in any other filter.

$F$ is an ultra filter $\Longleftrightarrow$ $F$ is the hull of a homomorphism $h: B \to \underset{\sim}{2}$

minimal Boolean algebra $\{0, 1\}$

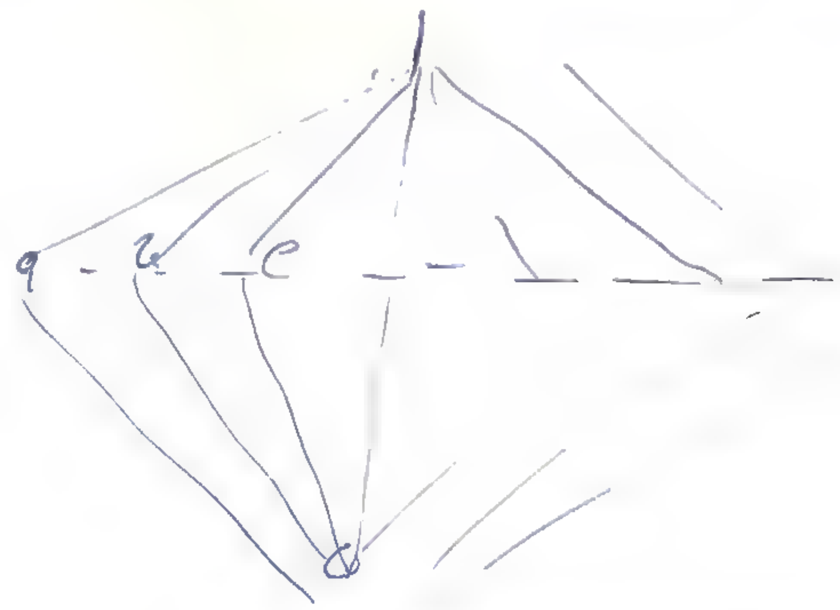
Minimum Boolean algebra $\underset{\sim}{2} = \langle 2, \leq \rangle$ where $2 = \{0, 1\}$.

Complemented lattice $\begin{cases} \forall x \in L, \exists y \in L \text{ s.t.} \\ x \vee y = 1, \; x \wedge y = 0 \end{cases}$

Distributive law $x \wedge (y \vee z) = (x \wedge y) \vee (x \wedge z)$
and $\Rightarrow$ $x \vee (y \wedge z) = (x \vee y) \wedge (x \vee z)$

Boolean algebra is a complemented distributive lattice

Eg




corresponds to 2-dimensional Hilbert space.
is not a Boolean lattice since.

$a$ and $(b$ or $c) = a$

while $(a$ and $b)$ or $(a$ and $c) = 0$ or $0 = 0$.

Fluctuations in electrical circuits

the Johnson Effect cf. (as opposed to the Shot effect in a vacuum Tube)

Barnes & Silverman R.M.P. vol 6 p.162 (1934)

References on Irreversibility

Grünbaum: Philosophical problems of space & Time

Reichenbach. The Direction of Time
— (Introduces Branch systems extended by Schrödinger

→ refers to Popper Nature.
Schrodinger's branch systems Proc. Royal Irish Academy 53 (1950) p.189
Penrose & Percival Proc. Phys Soc. 79 (1962) p.605.
Mehlberg.

Davies The Physics of Time Asymmetry (Surrey Univ. Press 1974)

Gold ed. The Nature of Time (Cornell Univ. Press 1967)

C Gale: Chinese Numerology.
Journal of the History of Ideas 35 (1974) p339

Weinberg Gauge Theories R.M.P. 46 (1974) p255.

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Penrose The Structure of Space-time
in Battelle Rencontres
1967 Lectures in Maths Physics
Ed. DeWitt & Wheeler 1968
(good acc of history of singularities
& grav. collapse - refers
to Hawking and extent
of other Einstein research)

Park: Int. J. theor. Phys. 8 (1973) p. 211

queries ignorance interpretation of neutrinos

Fino P.R. D2 2783 (1970) extends Wigner's proof of no velocities (+ d... etc)

Moldauer P. P.R D5 1028 (1972)

Reply by Fino P.R D5 1033 (1972)

→ refer to Wadlich for agreements etc.

Z. Physik. 205, 199 (1967)

Haake & Wadlich 213, 451 (1967)

[illegible] n.e. 17.

Fehrs ? Shimony P.R. D 9 (1974) p 2317

Shimony P.R. D 9 (1974 p 2321

~~[illegible]~~ [illegible] a [illegible]

Groen: N.C. 9 (1958) p 880

considers the effect of detecting well separated beams (as in Stern Gerlach) using a macroscopic apparatus (photo plate) or a metastable state. Explains how interference terms are eliminated, similar to Bohm's random phases introduced between the beams

Jost The general Theory of Quantized Fields (1965)

For Dirac 1927 "success & failure were immediate" "to understand the success" Dirac was able to derive ... to understand the relationship the already familiar rules describing the emission & absorption of light. The failure: P. Ehrenfest ... immediately pointed out that the theory had to lead to ∞'s because it contained as an essential quantity the value of the vector potential at the position of the point-electron".
cp Pauli W. Naturwissenschaften 21 (1933), 8 ff.

Renormalization has its roots in Heisenberg, Dirac & Weisskopf in the mid-thirties  Z. Phys 90 (1934) 209
Mat Fys Medd Danske Vid Selsk 14 (1936) no 6

We do not know if axioms are compatible with a non-trivial S-matrix, but they do exclude QED because of reliance on 'gauge-invariant' operators
Jost discusses PCT theorem & connection between spin-statistics
— also "abnormal" commutation relations

Comments from the *Philosophy of Karl Popper*
The Library of Living Philosophers ed. P.A. Schilpp
published by La Salle, Illinois. Open Court. 1974

Very good autobiography stresses argument with Schrödinger about irreversibility (arrow of time due to thermodynamics)

Bronowski stresses an asymmetry between falsification and verification for probability statements, refers to Egon Pearson, Popper denies this and refers to his theory of random finite sequences which maintains the asymmetry.

Lakatos ~~says~~ "Popper on Demarcation and Induction" pp. 241–273. says on p. 242. "The term "normative" no longer means rules for arriving at solutions, but merely directions for the appraisal of solutions already there"

Footnote 5. "I should like to say here that I always had doubts about whether this (no doubt progressive) problem-shift had not gone a bit too far. ... I have held that there might well be a limbo for a "genuine" heuristic which is rational and nonpsychologistic; refers to Proofs and Refutations p. 4, n. 4. (BJPS 14 1963/64)

Medawar Hypotheses, Imagination, reprint from the Art of the Soluble, 1971. p. 274 – 291.
stresses the pre-eminence of Popper on the hypothetico-deductive methodology – cites Whewell, Jevons as opposition to the inductivism of Mill, Pearson

Section IV discusses heuristics: what scientists do has never been the subject of a scientific, that is, an ethological enquiry. — no use looking at scientific papers – they conceal, indeed actively misrepresent the reasoning that goes into the work they describe. Also do not listen to what scientists say they do.

"The weakness of hypothetico-deductive system, insofar as it might profess to offer a complete account of the scientific process, lies in its disclaiming any power to explain how hypotheses come into being"

Eccles explains how Popper's philosophy prompted him to falsify his own hypotheses

Watkins gives account of indeterminacy – distinguishes metaphysical determinism and scientific determinism
Causality possibility of scientific prediction

Rueyvou wrote on Popper philosophy of Science > Suppes suggests statistical features of Q.M. are very non-standard (no joint dist. in general). Grunbaum gives good account on arrow of time - refer to his book Philosophical problems of space & time (1964)

Boyle very good account in favour of the Open Society - distinguishes "utopian" and "piecemeal" social engineering.

Quote from Poverty of Historicism p. 141
"What may be called the method of logical or rational construction, or perhaps the 'zero method' - the method of constructing a model on the assumption of complete rationality (and perhaps also on the assumption of the possession of complete information) on the part of the individuals concerned, and of estimating the deviation of the actual behaviour of people from the model behaviour, using the latter as a kind of zero coordinate."

In the bibliography reference is made to
Popper, 1974, Philosophy and Physics: Essay in defence of the objectivity of Physical Science.

p. 413-463

Donald Campbell gets credit as "evolutionary epistemologist" for the fact of views of a psychologist — psychological view of development as Kant's categories — with many references

eg. C.F. Wallraff, Philosophical Theory & Psychological Fact, 1961

H. Poincaré, Mathematical Creation in The Foundations of Science 1913

P. Souriau, Théorie de l'Invention 1881

Ernst Mach, On the part played by Accident in Invention & discovery, Monist, 6 (1896) 161-75.

Alexander Bain, The senses & the intellect, 1874
(Trial & error model of discovery)

S. Jevons Principles of Science, 1892

Campbell discusses H.A. Simon, The Sciences of the artificial, 1969
also A. Newell, J.C. Shaw, H.A. Simon
'Elements of a theory of human problem solving'
Psychological Review 65 (1958) p. 151-66

referred to by D.T. Campbell, 'Blind variation and selective retention in creative thought as in other knowledge processes', Psychological Review 67 (1960) p380-400.
cf also K.J.W. Craik The Nature of Explanation 1943.

refers also to R. Ackermann The Philosophy of Science 1970 re extension of Toulmin's evolutionary model. Toulmin goes → 'competing intellectual variants', concepts, beliefs etc. Careers + individual scientists

cf also G. Polya. Mathematics + Plausible Reasoning
vol. I Induction + Analogy in Mathematics
vol II Patterns of Plausible inference.
1954.

Note Campbell's distinction between 'blind' + 'random' questioned in Popper's reply

Further references on Measurement (after H. Brown)

<u>Fine</u> Proc. Camb. Phil. Soc. (1969) <u>65</u> 111
Phys. Rev. <u>D 2</u>, 2783 (1970)

<u>Sneed</u> (on Von Neumann) Phil. Science <u>33</u> (1966) p. 22
<u>also</u> use of Compton-Simon expt
to justify the Projection Postulate

Furry "Some aspects of the Q. theory of Measurement
in Lectures in Theoretical Physics Vol <u>VIII</u> - A
Univ. Colorado Press (1966) p. 47

<u>Park</u> Int. J. Theor. Phys. (1973) <u>8</u>, 211

Wigner R. M. P. 37, ~~19~~595 (37) (Phys II

(Giovanoree)

Popper Nature, 219, 682 (1968)

on Birkhoff, Von Neumann's a/c

of Q. Mechanics (Phys. 30

Fine (Q. Rech. 22)

Probability in Q. Mechanics

Kochen, Specker QM 27

Park, Margenau Q. M. 37.

Frauen Q. M. 45

Gibson Q. M. 2. Statistical theory of Q. Mechanics

Fine Q. M. 3 Local ...

References (additional)          Jauch H. Phys. Acta (1964) 37, 293

Measurement

Daneri, Prosperi, Loinger   Nucl. Phys. 33 297 (1962)
Nuovo Cimento 44B 119 (1966)
Rosenfeld Prog. Th. Phys. 222 (1965)

George, Prigogine, Rosenfeld. ~~Mat. Fys. Medd. Dan. Vid. Selsk.~~ Det. Kgl. Danske Vid. Selsk. Mat. fys. Medd.
Nature: vol. 240 (1972) p 25 Nov 72,
Hepp. Helv. Phys. Acta. 45 237 (1972)      vol 38 no 12 (1972)

Kripps Nuo Cim. 1B (1971) p 23 others
6B (1968) p. 1127
60B (1969) p 278, 61B (1969) p 22
Phil. Science 36, (1969) p 145.

Joint distributions

Prugovecki   Canad. J. Phys. 45 (1967) p 2173

Hidden variables

Bell, R.M.P. 38 447 (1966)
Physics 1, 195 (1965)

Gleason: J. Math. Mech. 6, 885 (1957)

Clauser, Holt, Horne, Shimony PRL 23 880 (1969)

Kocher, Commins: P.R.L. 18, 575 (1967)

Freedman, Clauser P.R.L. 28, 938 (1972)

(S-matrix Axioms Chew Physics 1 p. 77)

Q. Logic — Putnam: Beyond the Edge of Certainty

Gardner Phil. Sci. 38, 508 (1971)

Heelan. Synthese 21 (1970) p 2.

Landé: Foundations of Q. Theory 1955

New Foundations of Q. Mechanics 1965 LX

Bell LX on Bohm etc N. Cim. 57 B (1968), 523

Bub on hidden variables & Copenhagen Interpretation B J P S 19 (1968) p. 185 LX

Bohm & Bub R.M.P. 38 (1966) p 453. LX

Bohm P.R. 85 (1952) p. 166, 180 LX

Bohm & Aharonov: Experiment on EPR non-locality P.R. 108 (1957) p. 1070.

Papaliolios Test of 1st kind hidden variables P.R.L. 18 (1967) 622. LX

Wu & Shaknov P.R. 77, 136. (1950)

Kasday

Bohr P.R. 48 (1935) p 696

Furry P.R 49 (1936) p 393

Hove: Physica 21 517 (1955) ✓
25 268 (1959) ✓

Rosenfeld Nucl. Phys. A 108, 241 (1968) ✓

Jauch, Wigner, Yanase Nuovo Cim. 48 B (1967) p 144 ✓

Jauch Nucl. Phys. A 108 p. 245 (1968) ✓

Peres & Singer N.C. 15 (1960) p. 907

Daneri, Prosperi, Loinger  Nucl. Phys. 33 297 (1962)

explain relevance of ergodicity - approach to equilibrium state by taking time averages over fluctuating states. Measurement is then refer to approach to ergodicity in Bocchieri, Loinger. P. R 114 (1959) 948.

micro structure $\xrightarrow{}$ macro $\xrightarrow{\text{ergodic}}$
superposition  superposition  decomposition  practical
↳ irreversibility destroys initial correlation on the atomic scale.

Daneri, Prosperi, Loinger, Prosperi  Nuov Cim 44 B 119 (1966)

discusses specific example of scintillation counters, spark chamber, counter exchanges - attacks Jauch for ignoring the amplifier

Rosenfeld  Supplement. Prog. Theor. Phys. (1965) p. 222-231
"The Measuring Process in Q. Mechanics".
gives very clear account of the Italian argument.
- completes Bohr's approach.

Bub Nuov. Cim. 57 B (1968) 503
attacks the Italians — very clear summary of their work, but he suggests Bohr's views — do not prove them.

Jauch Helv. Phys. Acta (1964) 37, 293
His explanation is not valid for actual measurement process — stresses the defn of macroscopic observables, some discussion as in his book.
Mixture can always be distinguished from superposition by some measurement (this is not denied)

Hove Physica 21 (517) (1955)
discusses derivation of transport equations describing irreversible approach to statistical equilibrium of a system with many degrees of freedom.

Hove Physica 25 268 (1959)
continues with discussion of the ergodic behaviour of Q. Many-body systems

Rosenfeld Nucl. Phys. II 103 p. 241 (1961)
defends the orthodox Bohr theory of measurement
— discusses the consistency problem for measurement, praises the Helmholtz and attacks Jordan, Wigner, Yanase

refers to Ingraham. N.C. 9 (1958) 99 for claim that Hove's results violate Unitarity. (also attacks Ingraham's Briant)
— denied by Van Hove

Loinger Nucl. Phys. B 108, p245 (1968)
defends the Statistics against Jauch, Wigner, Yanase.

Jauch, Wigner, Yanase. Nuo. Cim. 48 B (1967) p144
give a very clear general account of their objection to the Statistics.

[illegible] the measurement is not to be sought in the macroscopic part of the measuring process — ergodic development which takes over place.

Jauch believes that "classical" be of [illegible] superpositions for real physical systems — classical systems have a restricted class of observables (e.g. only those observables which cannot "see" it)

They discuss further the possibility that a. [illegible] does not apply to macroscopic bodies

Bohr  Can Quantum Mechanical Description of Physical Reality be considered complete?

$[q_1, p_1] = [q_2\, p_2] = 0$ etc   write $q_1 = Q_1 \cos\theta - Q_2 \sin\theta$

$p_1 = P_1 \cos\theta - P_2 \sin\theta$

etc (rotation)

then $[Q_1, P_2] = 0$   so we can measure $Q_1\, P_2$ together

But $\left.\begin{array}{l} Q_1 = q_1 \cos\theta + q_2 \sin\theta \\ P_2 = -p_1 \sin\theta + p_2 \cos\theta \end{array}\right\}$ ∴ knowing $Q_1, P_2$ we can measure $q_1$ from $q_2$ or $p_1$ from $p_2$

This is true source of EPR paradox.

"influence on the very conditions which define the possible types of predictions regarding the future behaviour of the system" these conditions constitute an inherent element of the description of any phenomenon to which the term "physical reality" can be properly attached

Bell Physics I, 195 (1965)

gives illustration of hidden variable theory for spin $\frac{1}{2}$ — discusses the Bohm-Aharonov form of the E.P.R. paradox — introduces the locality assumption and then derives the Bell inequality contradicting the predictions of Q. Mechanics

Hepp Helv. Phys. Acta. 45 237 (1972)
discusses measuring apparatus having $\infty$ no. degrees of freedom.

$\mathfrak{A} \subset B(H_S \times H_A)$

we require $(\Psi_+ \otimes \Phi_+, A\, \Psi_- \otimes \Phi_-) = 0$.

for all feasible observations $A$.

Why He does not use time averaging to cancel phases.

coherence $\rightarrow$ disjoint states at $\infty$ times when coupled to a q. apparatus with $\infty$ no. of degrees of freedom.

ii. Hepp uses causality of the apparatus:

)

Krips N.C. 6 1127 (1968)

Requirement of objectivity

$\sum C_n |\phi_n\rangle \times |\psi_n\rangle$ is not correlated. why(?)

since $\phi_n$ eff. Rn on $\psi_n$

$$\text{Define } \overline{W}_t^{S+M} = \int_{t'-\tau/2}^{t'+\tau/2} dt \, W_t^{S+M} \int_{t'-\tau/2}^{t'+\tau/2} \sum_{nn'} C_n \bar{C}_{n'} |\phi_n(t)\rangle\langle\phi_{n'}(t)| \times |\psi_n(t)\rangle\langle\psi_{n'}(t)|$$

where $|\phi_n(t)\rangle \times |\psi_n(t)\rangle = \exp\left(-\frac{iH^{S+M}}{\hbar}(t-t')\right)|\phi_n\rangle \times |\psi_n\rangle$

$$\xrightarrow[\tau]{} \sum_n |C_n|^2 |\phi_n\rangle\langle\phi_n| \times |\psi_n\rangle\langle\psi_n|$$

N.C. 60 B (1969) 278.

Every elimination of $c_i \bar{c}_i$ terms on p. 289 by time averaging

N.C. 13 (1971) p.23

Feradies [illegible] in [illegible] taken [illegible]
by saying a system on a particular occasion
can have a "values" — we do not say
there is a unique [illegible] for a system
at time t for the system

<u>Trifiro</u> N. Cim. <u>60B</u> (1969), 278,
<u>61B</u> (1969), 12.
1B (1971), 23

discusses new [illegible] applied to measurement theory

Kreps Phil Science, 36, 145 (1969)
discusses Cat - SE - P.R. — obscure arguments to follow.

refers to
Sharp Phil. Sci. 28, 225 (1961)
who suggests interaction between obs + system never really vanishes
— very poor argument, but supported by Putnam in an accompanying note:

SB suggests there is nothing in the Reference to say x > p for a particular particle
cannot be ~~[illegible]~~ accompanied precisely (cf Popper) (→ may not be trouble)

→ Cat + photon is not a macro system.

<u>Landé</u> New Foundations of Q. Mechanics

attacks the duality ascribed to Q. Mechanics
electrons <u>are</u> particles subject to a
3<u>rd</u> Q. law (after Duane (1923) which
explains the reciprocal deflection (diffraction)
of the electron particles in terms of
a restriction on possible momentum
exchanges $\Delta p = h/L$. // periodic structure L
2 slits have a different periodic structure from
1 slit. Hence different deflections of the
electrons must occur.

It is not the electron which is spread out
but the "Fourier" components of the screen depend
on <u>all</u> the openings — it is this which controls
the pattern of electrons behind the screen.
Screen acts on the electron as a mechanical
<u>unit</u>.

Landé stresses that his work is directed
towards the demystification of Q. Mechanics

George, Prigogine, Rosenfeld

Mat. Fys. Medd. Dan. Vid. Selsk. Math Phys Medd

vol. 38, no 12 (1972)

Varadarajan — The Geometry of Q. Theory

discusses the logic of Q. Mechanics as in Jauch
defines observable, state:
 + proves Gleason's theorem in some detail
 All states can be described by density matrices

The second volume he deals with symmetries
— similar treatment to Jauch.

Bohm Q. Theory
 exp measurement → phase factors
 gives example of Stern Gerlach —
 interference or "recombination" of spins
 infeasible in practice → neutron thermodynamic
 argument

~~Bohm~~ Bell R.M.P. 38 447 (1966)

explains hidden variable example for 2 dimensional space.

- contradicts Von Neumann assumption.

refers to Gleason. - no dispersion possible if additivity argument is imposed on commuting operators. → result of a measurement same independently of what other measurements are being made.

- non-locality of Bohm's solution

George, Prigogine & Rosenfeld Nature 240 p.25 (1972)

Large atomic systems best investigated in the kinetic approach of statistical mechanics not the ergodic approach. This is the difference as opposed to the Stalian School.

- correlations are lost in both methods if present in the initial states

Superspace defined as direct product of H & its dual. i.e. Linear transformations (operators) are described as Tensors ↔ direct product space.

thus $L_{\mu\nu} x_\mu x_\nu \equiv y_\nu x_\nu$ where $y_\nu = L_{\mu\nu} x_\mu$.

$L_{\mu\nu}$ is an operator.

Projection operator defined in superspace separates out $\hat{\Pi}$-subdynamics - macroscopic level of description is the reduced description in terms of variables of the $\hat{\Pi}$-subspace evolution in $\hat{\Pi}$ space eliminates flow correlations - they are transferred to the delayed space.

human observer is described entirely within the $\hat{\Pi}$ subspace; his interaction does not influence it all the delayed subspace.

[illegible] [illegible] applied to average distribution densities, correlation functions.

refer to Prigogine: Non-Equilibrium Statistical Mechanics

Two directions of linear polarization
≡ 2 senses of circular polarization
≡ 2 values of spin in same direction

Wu & Shaknov P.R. 77 136 (1950) 2 photon decay of e+e- pair - correlation of polarizations.

discuss angular correlation of annihilation radiation agrees with prediction of Q Mechanics

Aharonov & Bohm P.R. 108 (1957) p. 1070

discusses the Wu-Shaknov experiment as a possible test of the E.P.R. paradox - calculate correlations assuming 1) Q. Mechanics 2) photons → neutrons when wave functions do not develop, Q.M. confirmed by the experiment

Peres & Singer N.C. 15 (1960) p. 907

reject photon-polarization as test of a paradox, attributed in - they regard this case, as a decisive test, unconvincing. Einstein's terms as a decision upset unconvincing a photon cannot be circ. polarized & linearly polarized at the same time.

they recommend experiment on 2 spin ½ particles

not on plate polarizations.

Bohm & Aharonov N.C. 17. 964 (1960).

reply to Peres and Singer, by pointing out that we measure energy flow associated with a polarization in field theory.

Two linearly polarised waves does prove. Circular polarization [illegible].

— their argument is probably correct

obviously $I_{k1}$, $I_{k2}$ can be measured as well as $I_{k+}$, $I_{k-}$, but in Q.M. these flow operators do not commute

$$I_{k1} = \frac{p_{k1}^2 + q_{k1}^2}{2} \qquad I_{k+} = \frac{(q_{k1} - p_{k2})^2 + (q_{k2} + p_{k1})^2}{2}$$

$$I_{k2} = \frac{p_{k2}^2 + q_{k2}^2}{2} \qquad I_{k-} = \frac{(q_{k1} + p_{k2})^2 + (p_{k1} - q_{k2})^2}{2}$$

$$A_k = \left(q_{ki} \cos(kx) + p_{ki} \sin(kx)\right) \frac{\epsilon_{ki}}{\sqrt{k}}$$

$q_k$ & $p_k$ do not commute.

Gleason J. Math. Mech. 6 (1957) p. 885

Proves as his main theorem:

For any measure $\mu$ on the closed subspaces of a closed (real or complex) Hilbert space of dimension at least 3, there exist a semi-definite self adjoint operator $T$ of the trace class such that $\mu(A) = \mathrm{Trace}(TP_A)$

for $P_A$ projection operator.

difficult mathematical proof

Frame functions

$\sum f(x_i) = W$

orthonormal basis

f is regular if $\exists$ T each such

$f(x) = (Tx, x)$

Every non-negative frame function in 3 or more dimensions is regular

— this result leads to the main theorem

Belinfante: A Survey of Hidden Variables Theories

Three kinds of theory: Zeroth kind involve self-contradictory postulates

First kind agrees essentially with Q. Mechanics e.g. Bohm

Second kind look like causal theories when applied to spatially separated systems which interacted in the past. — contradict Q. Mechanics

2 reasons for dissatisfaction with Q. Mechanics

1.) "If different members of ensemble $E_\psi$ are found after measurement to have different values $A_i$ of an observable $A$, then these individual systems must have been in different microstates"

additional hidden parameters $\xi$ then measurement of $\xi$ i.e. knowing $\psi$ & $\xi$ selects $\phi_n$

$$\psi \to \phi_n \quad \text{with} \quad n = n(\psi, \xi, \{\phi_i\})$$

Gleason, Kochen & Specker show that dependence on $\{\phi_i\}$ is essential.

2.) Non-locality aspect of Einstein, Podolsky, Rosen, measurement of 1 at $F_1$ depends on 2 at $F_2$.

PTO

Hidden variables do <u>not</u> tell us what are the values of certain observables. They tell us what <u>would be found</u> if we measure these observables in a certain way.

B. then deals with Zeroth order theory of Von-Neumann, Kochen & Specker, Gleason, Jauch & Piron.

K-S dealt with this :- [illegible] to assigning for any value of $\xi$ we can predict value of $J_n^2(\xi)$ without [illegible] 2 $\perp$ directions.

dependence of $n$ on $\{\Phi_c\}$ is described by
~~Turner~~ Turner (1968) J. Math Phys. 9, 1411
cf also Tersic (1966), N. Cim. <u>47</u> 841

B then deals with <u>1st order theories</u>
viz Bohm, Wiener & Siegel, Bohm & Bub & the experiments of Papaliolas for verifying these
– failed to disprove Q predictions

B continues by discussing theories of the 2nd kind

I discusses the experiments of Kocher & Commins, & Clauser & Holt using 2-photon correlations for an atom cascading towards its ground state.

They also discuss experiments where 2 photons are produced by an annihilating positronium atom

— Bleuler & Bradt, Wu & Shaknov, Langhoff, Kasday, Ullmann & Wu.

— refers to Furry (1936) & Bohm & Aharonov (1957) for how non-locality may be avoided, breakdown of Q. Mechanics for many-particle systems at macroscopic separations — Furry's box + mixture

Araki & Yanase P.R. 120 (1960) p. 622

refer to Wigner Z. Physik 131, 101 (1952)

we cannot measure quantities which do not commute with a conserved ideally quantity e.g. x component of spin if z component is conserved.

Approximate measurement is possible if apparatus is so large that it is a superposition of many states with different e.v.'s of the conserved quantity.

$L = L_1 \otimes 1 + 1 \otimes L_2$ $[U(t), L] = 0$.

$L$ is conserved. we want to measure. $M$.

$$V(t)\, \phi_{\mu e} \otimes \xi = \sum_{e'} \Phi_{\mu e'} \otimes X_{\mu e e'}$$

then is noticeable unless $[L, M] = 0$ this is proved

$M \phi_{\mu e} = \mu \phi_{\mu e}$ $(\phi_{\mu e}, \phi_{\mu' e'}) = \delta_{\mu\mu'} \delta_{ee'}$ ortho

$(X_{\mu e e''}, X_{\mu' e' e''}) = 0$, $\mu \neq \mu'$.

Approximate measurement is then discussed. large eigenvalues of conserved quantity must be possessed by the apparatus — agreed for macroscopic apparatus. RTV

where
$(\phi_{\mu}\otimes\xi, L\ \phi_{\mu}\otimes\xi)$

$= (U(t)(\phi\otimes\xi), U(t)L(\phi\otimes\xi))$ $\quad UU^{\dagger}=1$

$= (U(t)\phi\otimes\xi, L\ U(t)\phi\otimes\xi)$ $\quad$ since $U(t)$ commutes

$= \sum_{\chi'}(\phi\otimes\chi'), L\sum_{\chi'}(\phi\times\chi')$ $\quad$ by measurement theory.

If $L =$ ~~$L_1\otimes 1 + 1\otimes L_2$ as above~~. $L_1\otimes 1 + 1\otimes L_2$ as above.

then. L.H.S. $= (\phi', L\phi)(\xi\xi') + (\phi',\phi)(\xi, L_2\xi)$

R.H.S. $= \sum_{\chi'\chi''}(\phi' L_1, \phi'')(\chi', \chi'')$
$+ (\phi', \phi'')(\chi' L_2 \chi'')$

there of $\mu'\neq\mu$ $(\phi_{\mu}' L_1, \phi_{\mu}) = 0$.
where $L_1$ commutes with the $\phi$'s are eigenfunctions of $M$.

Yanase P.R. 123 (1961) p.660
extends the simple example of Wigner
$\sigma_x$ measured, $\sigma_z$ conserved, obtains
conditions for an "approximate" measurement.

Beck & Nussenzweig N.C. 9 (1958) p 1068

discuss diffraction by a slit

— they conclude uncertainty relations are not contradicted even of a narrow slit.

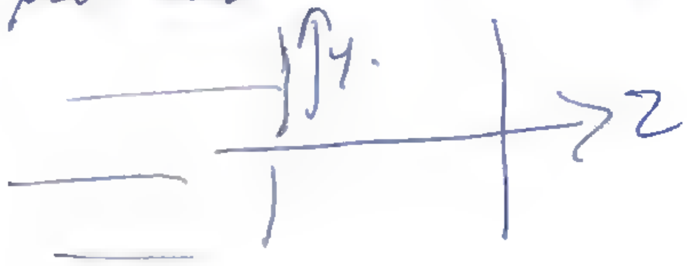
explain that

$S_{p_y}(\infty) \times S_y(0) \ll 1$ for a narrow slit

but this does not contradict H, since we ought to compare $S_{p_y}(0) \times S_y(0) \approx 4.6$ — satisfies H's relation.

B & N show that rt. mean sq. dev. $\Delta y$, $\Delta p_y$ are small and that $\Delta p_y(0)$ diverges logarithmically for a narrow slit — suggest replacing $\Delta p_y$ by the "½ width" of the prob. distribution in the [illegible].

$z = \zeta$



D'Espagnat (1966) N. Cim Supp 4 828 (1966)

refers to Wigner Am J. Phys. 31, 6 (1963)

for proof that mixture of states for apparatus

does not solve measurement problem.

What about non-ideal measurements.

Wigner's proof is extended to this case.

— also the question of the pointer position
not generally in a completely ($p=1$) state is
considered — shown to fail.

37 TV 235 0

D'E. refers to London, Lifschitz Q.M. (1958)

for discussion of non-ideal measurements.

(does not refer directly to Araki-Yanase,
but to Wigner (1952) by footnote

Earman & Shimony N/C. 54 B 332–334

'A note on Measurement'.

extends D'Espagnat's result to the case of degenerate eigenvalues for object.

Tomonaga Quantum Mechanics 1966. North-Holland
p. 231–238 ~~the~~ gives a time-dependent
account of diffraction & interference via 1 &
2-slit experiment
shows $\Delta y \Delta p_y \gg \hbar$ for diffraction at
the screen if $\Delta y \Delta p_y \approx \hbar$ for whole
packet (uncertainty product increases with
time, does not assume it is at a
minimum value.

Landau & Lifshitz  Quantum Mechanics

discuss on p. 21 the question of how measurement "disturbs" a state — they do not use the term non-ideal measurement.

Bunge  Foundations of Physics.

p. 265 states "Not every actual calculation for such idealized situations suffices to confirm Heisenberg's relation (Bohr, Newman very (1958)

Springer-Verlag (1967)

Proceedings of the International School of Physics « Enrico Fermi »

Course 49 Ed. B d'Espagnat, Academic Press.

Foundations of Quantum Mechanics

Stein H. & Shimony A. Limitations on Measurement. pp 56–74.

Wigner's article 6 reasons on collapse of state-vector

1.) the collapse see Everett

2.) classical memory evidences

3) Q.M. does not apply to macroscopic systems of tendency

4) collapse is an extra axiom of Q.M.

5.) Evidence[?] because of the classes no need to explain collapse.

6.) systems never entirely separable

Stein & Shimony [illegible] the Araki-Yanase [illegible] & see new proof of the Everett [illegible] result for the solution of measurement problem.

## Bohm's phase argument

we have $\psi = \nu_+ f_+(z,t) + \nu_- f_-(z,t)$.

$$\rightarrow \nu_+ e^{i\alpha_+(z,t)} + \nu_- e^{i\alpha_-(z,t)}$$

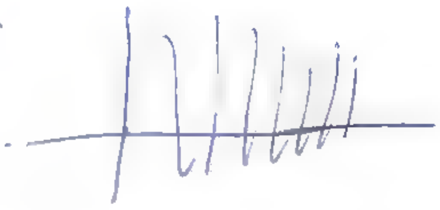
$\alpha_+(z)$ $\alpha_-(z)$ are very large phases.

we know that $\int dz\, f_+^*(z) f_-(z)$ is very small for good measurement.

$$\hookrightarrow \int dz\, e^{i(\alpha_+(z) - \alpha_-(z))}$$

these phase $\rightarrow \int dz\, e^{ikz} dz$ $k$ very large.

$\rightarrow 1/k$ very small.



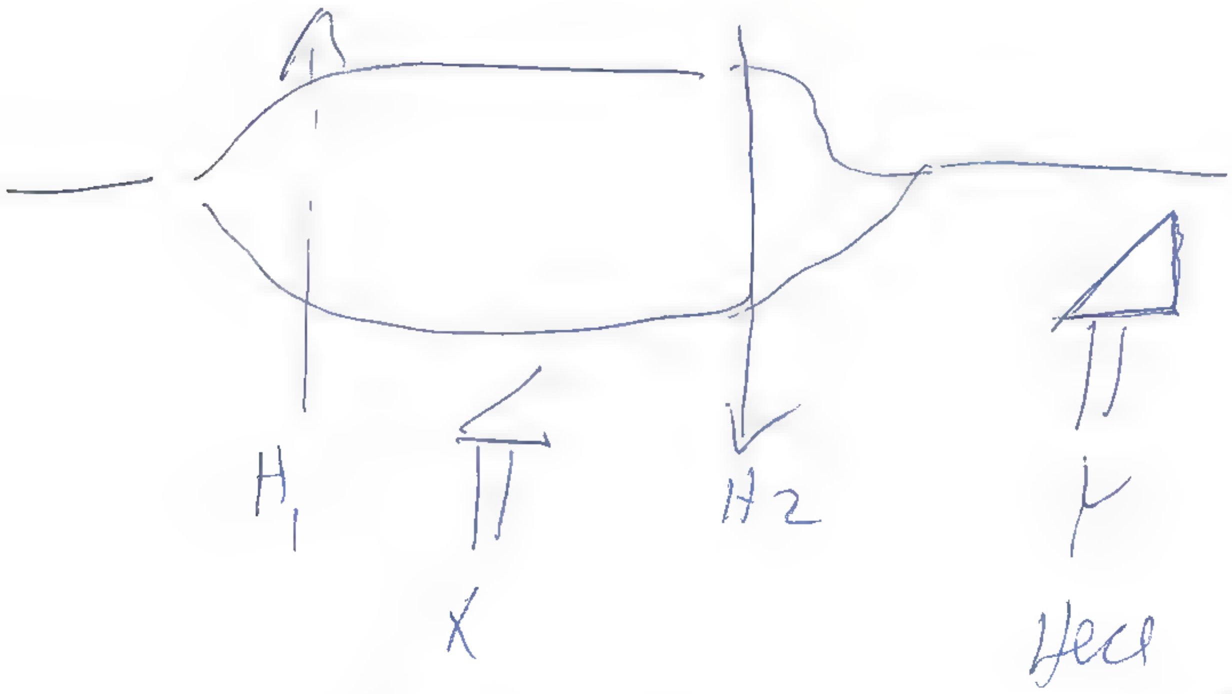
this applies even as beam here the wavepacket

— as beam $\rightarrow$ screen 2 blobs separate in space as well

beam wavepacket the interference due to large phases

on screen the interference are too small

## What Bohm fails to prove




Here
$\langle S_x \rangle = 0$ by Bohm
$1$ by Q.M.

Here
$\langle S_x \rangle = 0$ by Bohm
$= 1$ by QM.

Bohm gives no calculation to reconcile the contradiction between the phase argument and QM for measurement at Y.

Suppes Phil. Sci 28 313 (1961)

Margenau, Park Int. J. Theor. Physics 1, 211 (1968)

Fine Br. J. Ph. Science. (1973)

Park Phil. Science. 35 205, 389 (1968)
Found. Physics 1, 23 (1970)

Heelan Q. Logic. Found. Phys. 1, 95 (1970)

Feyerabend Pittsburgh Studies vol 3 1962

Linart Nuovo Cimento (1972).
(Simultaneity, determinism) 13 B no 2, 355

Tisza R.M.P. 35 no 1 (1963)

Baker & Glasstow Position operators P.R. 128 2462 (1962)

Lee Review article on Symmetry in:—

Journals Philosophy of Science
Synthese
Theoria
Brit. J. Phil. Science
Foundations of Physics

Suppes (1961) Phil. Sci. 28 378.

Discusses joint probability distributions
characteristic function for 2 variables is

$$\phi(u,t) = \cancel{\text{Exp}}\ E\left(e^{itx + iuy}\right)$$

then $f(x,y) = \frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-itx - iuy}\,\phi(t,u)\,dt\,du.$

where $\phi(t,u) \equiv \left(\psi, e^{i(u\cancel{p}x + t\cancel{y})}\psi\right)$

then for harmonic oscillator in ground state
$f(x,y)$ is $\geq 0$ , genuine or proper prob. density
but not in excited state.

Cohen (1966?) Phil. Sci 33, 317.

presents more detailed arguments
relating to Margenau, Cohen's paper on d'th, ability.
The general form of $F(q,p)$ is referred to
properties of the characteristic function
$M(\theta,\tau) \longrightarrow \sigma(\theta,\tau)\, M_q(\theta)\, M_p(\tau)$
defined $\sigma(\theta,\tau)$.
then $F(\theta,\tau)$ is defined in terms of $\sigma(\theta,\tau)$

to [illegible] lead to Cole, Rayeeu's result.

The infeasibility of a stochastic theory is demonstrated from the special case.

$$\pi\left(g(\varepsilon,p)\right) = g^2(\varepsilon,p)$$

then $g^{(2)}(\varepsilon,p) \neq g^2(\varepsilon,p)$

Refers to Bohm's theory as analogous to Brownian motion, resp. his objection applies to Bohm's theory i.e. if carried through completely it would contradict Q. Mechanics

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Rayeeu still [illegible]

Starting from $\mathrm{Cov}\, XY = \frac{\langle 2\{XY\}/4\rangle - \langle X\rangle\langle Y\rangle}{\langle 2\{X^2+Y^2/2\}/4\rangle^2}$

they derive $P(q,p)$ from $\mathrm{Cov}\, XY = \sum P(x,y)\, x_i y_i - \bar{x}\,\bar{y}$

but find negative values

Cohen (1966a) J. Math. Phys. 7, 781 (1966a)
derives general form for $F(p,q)$
starts with $F(p,q) \to$ characteristic function
↳ expand in terms of [illegible]
↳ apply correspondence rule.
of general form.

Wigner (1932) P.R. 40, 749:
derives a quasi joint probability distribution for $P(x_1 \ldots x_n, p_1 \ldots p_n)$
which has correct marginal properties but which may be negative → it cannot be interpreted as a genuine probability.

Margenau & Hill (1961) Prog. Theor. Phys. 26, 722.
distinguishes 3 grades of causality (causal description)
1.) successive measurements give different results — completely statistical theory — cf. Margenau or [illegible]
2.) successive measurements give same but unknown result — this is Von Neumann's projection postulate
3.) measurement results are predictable.
they suggest $P(q,p) = (q,\psi)^2 (p,q)^2$ is wrong.
but $P(q,p) = (\psi,q)^2 (\psi,p)^2$ is all right but gives no correlation, but gives correct marginal distribution

Moyal (1949) Proc Camb Phil Soc 45 p 99

introduces joint probabilities using characteristic functions.
— discovers negative joint-functions — can be used as aid to calculations, but when
— ie. it is not an observable quantity.
If $F(p,q) > 0$ at time $t_0$, it will remain always $> 0$.
$F(p,q)$ is not unique for a given state, but depends on variables one is going to measure. — first hint of Cohen's results...

Fine (1968) Ph. Sci <u>35</u>, 101

distinguishes between statistical variables, random variables. The latter always have joint distributions, the former do not: ∴ concludes non-classical logic and non-classical probability theory are <u>not</u> involved in Q. Mechanics

<u>Suppes</u> (1966) Phil Sci <u>33</u>, 14

sets out the argument for non-classical logic in Q. Mechanics based on the idea that algebra of events must be such that probabilities are assigned to all events (but conjunction of events [illegible])
Notes that Reichenbach's 3-valued logic is <u>not</u> relevant to Q. Mechanics cited.
– is not truth functional in the 3 values

Boyer P.R. D8 (1973) p. 1679
Aharonov - Bohm effect
Expt. tests of Q. Mechanics

Kershaw Univ. Maryland Report (1973)
Expt tests Q. Mechanics

?) Reisenfeld Dancke - (1973 oct)
Phys of measurement problem

Varadarajan    Comm. Pure. Applied Maths $\underline{15}$ (1962) p 189.

discusses probability in physics
the generalization of Kolmogoroff arises when sample space is a non-Boolean lattice.
refers to Segal Amer. J. Math $\underline{76}$ (1954) p. 721
for discussion of abstract probability spaces.

Segal considers algebra of random variables
$\longrightarrow$ generalizes to a non-commutative algebra

V. proves in general 2 observables do not have a joint distribution.
$x, y$ have a joint distribution if there exists a $\sigma$-homomorphism $z$ of Borel sets of plane $R^2$ into $\mathcal{E}$
such that $z(E \times R^1) = x(E)$  $z(R^1 \times E) = y(E)$
for all Borel sets $E$. (joint distribution function is $p(z(R^2))$)
V proves joint distribution $\Longleftrightarrow$ $x, y$ are simultaneously observable
$x_\lambda = u_\lambda(x)$ is condition for this in Hilbert space.
i.e. all $x_\lambda$'s functions of some observable $x$

Note random variable → observable
$F(\Omega)$ ↳ $\sigma$-homomorphism.
$E \to x(E)$ is projection

probability of r.v.
having a value
is replaced by probability
of observable having a value.

Joint distribution is undef. of 2 observables
having given values and [illegible] marginal
distributions — there are related [illegible]
the probability measure on the sample
space — joint distribution [illegible]
to the observables (a generalized r.v.'s)

Prugovecki Can. J. Phys. 45 (1967) p 2173

2 interpretations of uncertainty relations:

1) statistical – standard deviations on an ensemble of systems

2.) minimal error in knowledge of $x$ & $p_x$ of the same system after an experiment.

Jedenberg [illegible] only [illegible] heuristic value.
W. [illegible] refers to a statistical [illegible]

(1.) is a deterministic measurement.
(2) is a separating measurement.

Introduces 2 probabilities
① probability of a joint measurement $p^{(+)}$
② error in determining $p^{(+)}$ (vs $p^{-}$) [illegible] $N \to \infty$

Introduce complex probability measure.
$$p = p^{(+)} + p^{(-)}$$

Prugovecki tries to deal in general with the problem of what is meant by a joint distribution of incompatible observables by a generalization of the probability calculus which is designed for compatible observables.

Thus a probability distribution in general refers to outcome of experiment as individual errors $\to 0$ and $N \to \infty$, but for macroscopic objects the errors of the individual measurement are bounded from below; so observed distribution are only approximate a theoretical one.
— the concept of probability must be generalized

Joint Probability distributions

Quantum Mechanics as a classical stochastic theory:

P.R. Wigner (1932) ⊙ — Proc. Nat. Phys. Margenau & Hill ⊙ (1961)

Proc. Camb. Phil. Soc. Moyal (1949) ⊙

Ph. Sci. Suppes (1961) ✓ Probability concepts in Q. Mechanics — Phil. Sci. Fine (1968) ✓ Logic prob. & Q. theory

Cohen J. Math. Phys. (1966a) ⊙, (1966b) Phil. Sci. Can Q. Mech. be formulated as a classical prob. theory

Margenau & Cohen (1967) ✓ Probabilities in Q. Mechanics — Prrijovecki Can J Phys. (1967), 45, 2173

Bunge vol. Q. theory & reality. Ballentine (1970) (R.M.P.)

Non-Interference of Measurement

P.R. Margenau (1937) ✓ Phil Sci

Ann. Phys. Margenau (1963a) ⊙, (1963b) ⊙

Int. J. Theor. Phys. Margenau & Park (1968) ✓ Simultaneous Measurability in Q. Theory. Int. J. Theor Phys.

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P.R. She & Hefner (1966)

Ronninger (1960)

Park. (1972, 3?) Int J. Theor Phys. (Model for State Prep.)

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Found. Phys. Heelan (1970)

Nature Popper (1968)

Ph. Sci. Gardner (197[illegible])

Van Fraassen (1973)

Birkhoff & Von Neumann (1935)

Phil. Sci. Suppes (1966)

Varadarajan (1962) probab. calculus on a Q. Logic

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R.M.P. Bohm & Bub (1966)

R.M.P. Bell (1966)

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✓ Bohm : Phys. Rev. 85, 166, 180 (1952)

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Araki & Yanase P.R. 120 622 (1960)

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Weele  Relativistic theory of Reactions

Halpern  Special relativity & Quantum Mechanics ✓

Kuhn  The Structure of Scientific Revolutions ✓

Smart  Philosophy & Scientific Realism ✓

Popper  Logic of Scientific Discovery ✓

J. Taylor  Concept of the Mind

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Rose  Vibration & Sound ✓

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Omnes  Introduction to Particle Physics ✓

D'Espagnat  Conceptual Foundations Q. Mechanics ✓

?  Molecular Reality

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| Mach [illegible] | Mechanics |
| Hertz | Mechanics |
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